Comparison of Heat Transfer Performance of Shell & Tube Heat Exchanger and Double Pipe Heat Exchanger for CNT/Water Nanofluid

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***Abstract*—Experimental Studies of Heat Transfer of CNT (Carbon Nano Tube) Water based Nanofluid in a Shell and Tube Heat Exchanger and double pipe heat exchanger has been performed by varying flow rate and concentration of nanoparticles from 2 LPM to 4 LPM and 0.1% to 0.3% by volume respectively at ambient temperature. The increment in heat transfer coefficient was determined for both cases and compared. It was found that the increment in heat transfer performance in shell and tube heat exchanger is better in comparison to double pipe heat exchanger.**

***Index Terms*—shell and tube heat exchanger, double pipe heat exchanger, carbon nano tubes, nanofluids, convective heat transfer coefficient**

I. INTRODUCTION

In many power generations, manufacturing etc. industries fluid heating and cooling plays a very important and crucial role. Commonly these industries used water, ethylene glycol, oil as the heat transfer fluid but they have very poor heat transfer properties. To increase the heat transfer properties of these fluids solid particles are mixed into it as they have higher thermal conductivities. The commonly used particles that are used to increase the heat transfer property are CNT, Al_2O_3, ZnO, CuO, TiO_2 etc. Out of these particles the heat transfer is found maximum in case when CNT is mixed in the fluid due to its very high thermal conductivity. Clogging of flow channels, erosion of pipelines etc. are some of the major hurdles that arise due to the small size of the particles. Because of such issues practically suspended particles slurries have not utilized in industries. Many scientists and researchers have done a numerous work in this field and found nanofluids to be a better option for using in the heat exchanger [1]. [2] Li and Xuan have performed experiments to enhance the heat transfer coefficients using Cu water nanofluids in heated tube and observed an increase of 60% in the value of heat transfer coefficients when compared to pure water both in laminar and turbulent flow. The heat transfer experiments are generally done using heat exchangers like shell and tube heat exchanger, double pipe heat exchanger etc. for example [3] used double pipe heat exchanger to investigate the convective heat transfer coefficient of nanofluids made of alumina nanoparticles. [4] also shows the effect of α-Al_2O_3 in both double pipe and shell and tube heat exchanger. Different papers focused on experimental investigation in both laminar [5]-[8] and turbulent regimes [9], [10] of Nano fluids convection reported in literature. In this study, the enhancement of convective heat transfer was done using CNT water Nanofluid flowing in a shell and tube heat exchanger and double pipe heat exchanger. The effect of concentration of CNT nanoparticles and flow rates on convective heat transfer was investigated for both the heat exchanger and was compared.

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II. EXPERIMENTAL

A. Materials

The chemicals procured from Glaxo Chemicals Ltd., India. The size of CNT used was 5-10 nm and was 95% pure. Triton X-100 was used as a mixing agent.

B. Experimental Set-up

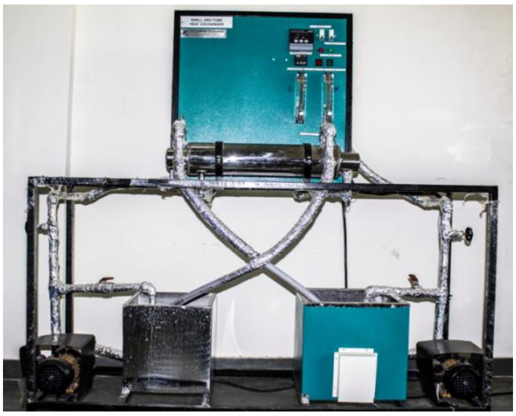

Figure 1. Shell and tube heat exchanger.

Fig. 1 and Fig. 2 shows the experimental apparatus for the study of variation in heat transfer coefficient using CNT nanoparticles. Shell and tube heat exchanger and double pipe heat exchanger were used in turbulent flow region. The shell and tube heat exchanger and double pipe heat exchanger both consists of a test section having dimensions straight steel tube with 12.7 mm inner diameter and 0.5 m length in case of shell and tube heat exchanger and straight steel with inner tube dimension do = 18mm, di = 15mm and outer tube dimension Do = 36mm, Di = 132mm. The length of both the tubes are

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1.5m in case of double pipe heat exchanger, a pump, a reservoir tank and a circulator. A 150mm thick insulation was done on both the heat exchange for minimization of heat loss form tube to ambient. For the measurement of the wall temperature of the steel tube and the mean temperature of the fluids at the inlet four thermocouples were used in both heat exchangers. The flow rate of the fluids was kept in the range from 2 to 4LPM. Heated fluid was re-circulated to keep constant temperature at the inlet of the test section. The composition of CNT nanoparticle in water was varied from 0.1% to 0.3% by volume.

Figure 2. Double pipe heat exchanger.

C. Nanofluid Physical Properties

Base fluid properties are:
Density= 994.7 kg/m3, specific heat = 4170.7 J/kgK, thermal conductivity = 0.615 W/mK,
Viscosity= 0.000547 kg/ms
Properties of CNT are:
Density= 2000 kg/m3, specific heat = 550 J/kgK, thermal conductivity = 3500 W/mK

TABLE I. EFFECTIVE THERMOPHYSICAL PROPERTIES OF CNT – WATER SAMPLE

Sample	Density (Kg/m^3)	K (W/mK)	C_P (J/KgK)	Viscosity (Kg/ms)
Water	994.7	0.615	4170.7	0.000547
Water + 0.1% CNT	995.7	0.650	5289	0.000548
Water + 0.2% CNT	996.7	0.654	5280	0.000549
Water + 0.3% CNT	997.7	0.658	5248	0.00055

The experimental data were used to calculate the Nusselt number and Reynolds number of Nanofluid for various nanoparticle volume concentrations. The thermo physical properties were calculated on mean bulk temperature of Nanofluid. Equation 1, 2, 3 and 4 were used to evaluate the effective viscosity, density, heat capacity and thermal conductivity and the results were tabulated in Table I.

1. Viscosity of Nano fluid: - Drew and Pass man relation[11]:

$$\mu_{nf} = \mu_{bf}(1 + 2.5\emptyset) \tag{1}$$

2. Density – Choi Correlation[12]:

$$\rho_{nf} = (1 - \emptyset)\rho_{bf} + \emptyset\rho_P \tag{2}$$

3. Heat Capacity equation :Xuan and Roetzel [13]:

$$C_{pnf} = \frac{(1-\emptyset)\rho_{bf}C_{p_{bf}} + \emptyset\rho_p C_{p_p}}{\rho_{nf}} \tag{3}$$

4. Effective thermal conductivity: Yu and Choi Model[14]:

$$K_{nf} = \frac{[K_p + 2K_{bf} + 2(K_p - K_{bf})(1+\beta)^3\emptyset]K_{bf}}{[K_p + 2K_{bf} - (K_p - K_{bf})(1+\beta)^3]} \tag{4}$$

III. RESULTS AND DISCUSSION

All the experimental runs were performed at ambient temperature 32±3oC using CNT/water nanofluid. The experiments were done at different nanoparticle concentration (0.1% to 0.3% by volume) and flow rate (2-4 LPM) in both shell & tube heat exchanger and double pipe heat exchanger. The comparative studies of increment in heat transfer performance were done and the results are summarized below.

A. Effect of Concentration of Nanoparticles and Flow Rate

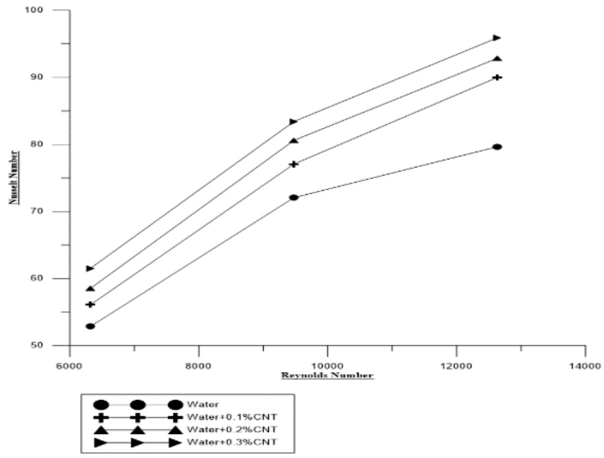

Figure 3. Variation of nusselt number with reynolds number for CNT nanofluid in shell and tube heat exchanger.

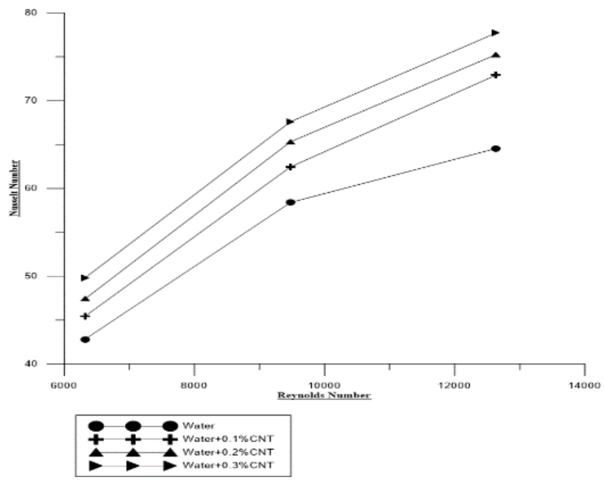

Figure 4. Variation of nusselt number with reynolds number for CNT nanofluid in double pipe heat exchanger.

The effect of nanoparticle concentration in base fluid and flow rate of nanofluid on the increment of nusselt number with Reynolds number is shown in Fig. 3 and Fig. 4 for shell & tube heat exchanger and double pipe heat exchanger respectively. This may be due to improved thermo physical properties of the mixture with respect to the base fluid yields in the increase in heat transfer and Nusselt Number. [16], [17] shows similar result.

B. *Effect of Heat Exchanger in Increment of Nusselt Number*

Fig. 5 shows the comparison of increase in Nusselt number in shell and tube heat exchanger and double pipe heat exchanger at different flow rate. The increase in Nusselt number in case of shell and tube heat exchanger at same Reynolds number in comparison to double pipe heat exchanger.

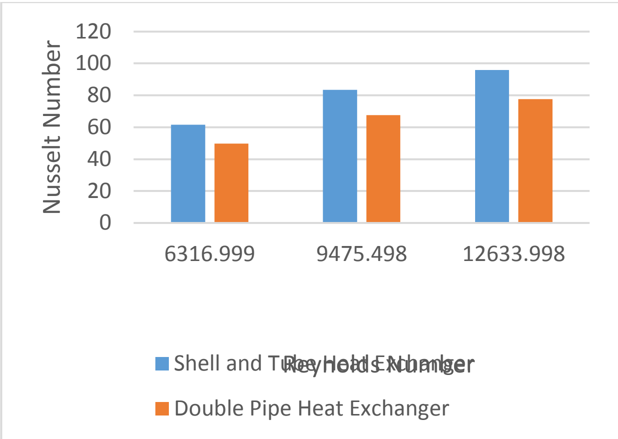

Figure 5. Comparative graph of increase in nusselt number for 0.3%CNT in different heat exchanger

IV. CONCLUSION

The convective heat transfer coefficient of CNT/water nanofluid in shell and tube heat exchanger and double pipe heat exchanger was determined experimentally. By the above stated results the following conclusions are made:

1. In case of both the heat exchanger as the concentration of nanoparticle in water increases it increases the heat transfer coefficient of the nanofluid.
2. The increase of heat transfer coefficient also depends proportionally on the flow rate of the nanofluid.
3. The heat transfer performance of CNT/water nanofluid in a shell and tube heat Exchanger is approximately 24% higher in comparison to double pipe heat exchanger.

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REFERENCES

[1] S. Choi, "Enchancing thermal conductiviy of fluids with nanoparticles," *Developments and Applications of Non-Newtonian Flows, ASME FED*, pp. 99-105, 1995.

[2] Q. Li and Y. Xuan, "Convective heat transfer and flow characteristics of Cu-water nanofluid," *Science in China (Series E)*, vol. 45, no. 4, pp. 408-416, 2002.

[3] B. H. Chun, H. U. Kang, and S. H. Kim, "Effect of alumina nanoparticles in the fluid on heat transfer in double-pipe heat exchanger system," *Korean J. Chem. Eng.*, vol. 25, no. 5, pp. 966–971, 2008.

[4] M. Akhtari, M. Haghshenasfard, and M. R. Talaie, "Numerical and experimental investigation of heat transfer of α-Al_2O_3/water nanofluid in double pipe and shell and tube heat exchangers," *Numer. Heat Transf. Part A Appl.*, vol. 63, no. 12, pp. 941–958, 2013.

[5] S. Suresh, K. P. P. Venkitaraj, P. Selvakumar, and M. Chandrasekar, "Effect of Al_2O_3–Cu/water hybrid nanofluid in heat transfer," *Exp. Therm. Fluid Sci.*, vol. 38, pp. 54–60, 2012.

[6] S. Halelfadl, P. Estellé, and T. Maré, "Heat transfer properties of aqueous carbon nanotubes nanofluids in coaxial heat exchanger under laminar regime," *Exp. Therm. Fluid Sci.*, vol. 55, pp. 174–180, 2014.

[7] S. M. Hashemi and M. A. Akhavan-Behabadi, "An empirical study on heat transfer and pressure drop characteristics of CuO-base oil nanofluid flow in a horizontal helically coiled tube under constant heat flux," *Int. Commun. Heat Mass Transf.*, vol. 39, no. 1, pp. 144–151, 2012.

[8] A. Ghozatloo, A. Rashidi, and M. Shariaty-Niassar, "Convective heat transfer enhancement of graphene nanofluids in shell and tube heat exchanger," *Exp. Therm. Fluid Sci.*, vol. 53, pp. 136–141, 2014.

[9] M. M. Heyhat, F. Kowsary, A. M. Rashidi, S. A. V. Esfehani, and A. Amrollahi, "Experimental investigation of turbulent flow and convective heat transfer characteristics of alumina water nanofluids in fully developed flow regime," *Int. Commun. Heat Mass Transf.*, vol. 39, no. 8, pp. 1272–1278, 2012.

[10] Z. Wu, L. Wang, and B. Sundén, "Pressure drop and convective heat transfer of water and nanofluids in a double-pipe helical heat exchanger," *Appl. Therm. Eng.*, vol. 60, no. 1-2, pp. 266-274, 2013.

[11] D. Drew and S. Passman, *Theory of Multicomponent Fluids*, Berlin, 1999.

[12] D. Kumar, S. Choi, and H. Patel, "Heat transfer in nanofluids-a review," *Journal of Heat and Mass Transfer*, vol. 43, pp. 3701-3707, 2000.

[13] Y. Xuan and W. Roetzel, "Conceptions for heat transfer correlation of nanofluids," *International Journal of Heat and Mass Transfer*, vol. 43, no. 19, pp. 3701-3707, 2000.

[14] W. Yu and U. Choi, "The Role of international layers in the enhanced thermal conductivity of nanofluids," *A Renovated Maxwell. Journal of Nanoparticles Reasearh*, vol. 5, pp. 161-171, 2003.

[15] A. Zamzamian, S. N. Oskouie, A. Doosthoseini, A. Joneidi, and M. Pazouki, "Experimental investigation of forced convective heat transfer coefficient in nanofluids of Al2O3/EG and CuO/EG in a double pipe and plate heat exchangers under turbulent flow," *Experimental Thermal and Fluid Science*, vol. 35, no. 3, pp. 495–502, 2011.

[16] W. Duangthongsuk and S. Wongwises, "An experimental study on the heat transfer performance and pressure drop of TiO2-water nanofluids flowing under a turbulent flow regime," *International Journal of Heat and Mass Transfer*, vol. 53, no. 1, pp. 334–344, 2010.

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